Abstract

One way the ultraviolet problem may be solved is explicit physical regularization. In this scenario, QFT is only the long distance limit of some unknown non-Poincare-invariant microscopic theory. One can ask how complex and contrived such microscopic theories should be.

We show that condensed matter in standard Newtonian framework is sufficient to obtain gravity. We derive a metrical theory of gravity with two additional to GR cosmological constants. The observable difference is similar to homogeneously distributed dark matter with $p = -\frac{1}{3}\varepsilon$ resp. $p = \varepsilon$. The gravitational collapse stops before horizon formation and evaporates by Hawking radiation. The cutoff is not the Planck length, but expanding together with the universe. Thus, in some cosmological future microscopic effects become observable.

Quantization of Gravity Based on a Condensed Matter Model

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1 Introduction

Most of the research in quantum gravity relies on the assumption that current observable symmetries, especially local Lorentz symmetry, are fundamental symmetries of our universe. Different directions (Grand Unification, supersymmetry, tetrad formalism, Ashtekar variables, strings, M-theory) may be interpreted as different attempts to interpret current observable symmetries as parts of greater, more fundamental symmetry groups. A high degree of symmetry is required to cure the problems with ultraviolet divergences.

But the observable symmetry groups may be simply a consequence of "blindness for details" at long distances. In this case, below a critical length QFT should be replaced by an unknown microscopic theory which does not have these symmetries. In this case, the ultraviolet problems are cured by explicit, physical regularization. Unlike in renormalized QFT, here the relationship between bare and renormalized parameters obtains a physical meaning. Such ideas are quite old and in some aspects commonly accepted among particle physicists [8].

Usually it is expected that the critical cutoff length is of order of the Planck length $a_P \approx 10^{-33} cm$. Below this distance, not only Poincare invariance may break down. Even the laws of quantum mechanics need not hold.

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Instead of a single space-time we may have to face topological foam. There seems to be no chance that such theories lead to testable predictions.

The theory we present here shows that these expectations are not justified. First, the microscopic theory we present here is surprisingly simple – usual condensed matter in a Newtonian framework, canonically quantized in classical Schrödinger theory. Second, the cutoff length in this theory is not related with Planck length. In the expanding universe, it looks expanding together with the universe. Thus, in some cosmological future we will be able to test the microscopic theory even with our current experimental devices. Last not least, the theory leads to testable predictions – we obtain two additional cosmological constants. This leads to observable effects similar to homogeneously distributed dark matter with $p = -1/3\varepsilon$ resp. $p = \varepsilon$.

2 The Theory

The microscopic theory we consider is a standard condensed matter theory in the Newtonian framework $R^3 \otimes R$. That means, for long distances it should be described by a density $\rho(x,t)$, a velocity $v^a(x,t)$, and a stress tensor $\sigma^{ab}(x,t)$. There may be some additional inner steps of freedom $\phi^m(x,t)$, but no external forces. That's why the conservation laws have the following form:

$$\partial_t \rho + \partial_i(\rho v^i) = 0 \tag{1}$$
$$\partial_t(\rho v^j) + \partial_i(\rho v^i v^j - \sigma^{ij}) = 0 \tag{2}$$

Now we introduce new variables. First, we combine the ten classical steps of freedom into a metrical tensor:

$$\hat{g}^{00} = g^{00}\sqrt{-g} = \rho \tag{3}$$
$$\hat{g}^{a0} = g^{a0}\sqrt{-g} = \rho v^a \tag{4}$$
$$\hat{g}^{ab} = g^{ab}\sqrt{-g} = \rho v^a v^b - \sigma^{ab} \tag{5}$$

For Galilean transformations this tensor transforms like a Lorentz metric. Instead of searching for a coordinate-dependent Lagrange function $L(g_{ij}, \phi^m, t, x^a)$ we introduce the preferred Galilean coordinates as independent fields $X^a(x)$, $T(x)$ and try to find a covariant Lagrange function

$$L = L(g_{ij}, \phi^m, T, X^a).$$

The advantage is that in these variables the conservation laws are already covariant equations for X^a and T:

$$\Box T(x) = 0; \ \Box X^a(x) = 0;$$

and for these equations a covariant Lagrange function is well-known:

$$L_0 = C_T g^{ij} T_{,i} T_{,j} + C_X \delta_{ab} g^{ij} X^a_{,i} X^b_{,j}$$

L_0 looks really nice in the original Galilean coordinates:

$$L_0 \sqrt{-g} = C_T \rho + C_X \delta_{ab}(\rho v^a v^b - \sigma^{ab})$$

We split the Lagrange function into L_0 and a remaining part and require that the remaining part no longer depends on X^a and T:

$$L = L_0 + L_1(g_{ij}, \phi^m)$$

This is the simplest way to fulfil our initial requirements. But the requirements for L_1 are the same as for Lagrange functions in general relativity with matter fields ϕ^m. Thus, we obtain a one-to-one relation to relativistic theory:

$$L = L_0 + L_{rel}(g_{ij}, \phi^m) = L_0 + R + C_E + L_{matter}(g_{ij}, \phi^m)$$

with scalar curvature R, Einstein's cosmological constant C_E and a matter Lagrangian. For every relativistic matter Lagrangian we obtain a related condensed matter theory of some "ether" with inner steps of freedom ϕ^m.

The non-gravity limit of this theory is de-facto Lorentz ether theory. Clock time dilation and contraction of rulers may be derived as in general relativity as a consequence of the symmetry of the matter Lagrangian. Thus, the theory solves the conceptual problems of Lorentz ether theory (insufficient explanation of Lorentz symmetry, no influence of matter on the ether, no possibility to observe the ether) by generalization to gravity. This suggests to name it "general ether theory".

3 Predictions

Let's consider now the homogeneous universe solutions of the theory. Because of the Newtonian background frame, only a flat universe may be homogeneous. Thus, the theory prefers a flat universe. We make the ansatz

$$ds^2 = d\tau^2 - a^2(\tau)(dx^2 + dy^2 + dz^2).$$

Note that in this ansatz there is no expanding universe but shrinking rulers. With some homogeneous matter $(p = k\varepsilon)$ we obtain

$$
\begin{aligned}
G_0^0 &= +C_T/a^6 + 3C_X/a^2 + C_E + \varepsilon \\
G_a^a &= -C_T/a^6 + C_X/a^2 + C_E - k\varepsilon
\end{aligned}
$$

The parts with C_T, C_X cause effects similar to homogeneously distributed dark matter with $p = \varepsilon$ resp. $p = -\frac{1}{3}\varepsilon$. Thus, the preferred Newtonian frame leads to observable effects, as a special type of "dark matter".

Another prediction is the time-dependence of the cutoff length. The critical length where the continuous approximation of a condensed matter theory fails is related with the density:

$$\rho(x,t)V_{crit} = const$$

In the case of the flat homogeneous universe, the density $\rho(x,t)$ and that's why the cutoff length is approximately constant in harmonic space coordinates. That means, the cutoff length is not related with Planck length, but seems to increase together with the observable universe expansion. In the early universe, it was below Planck length, and in some cosmological future it becomes observable even for our current devices.

If we set $C_T = C_X = 0$, we formally have the Einstein equations of general relativity in harmonic coordinates. Nonetheless, the theory remains different from general relativity in harmonic gauge (cf. [9]) even in this limit. There remains another notion of completeness of the solution. The solution is complete if it is defined for all X^a, T, the metric should not be complete. An example is the black hole collapse. Starting the collapse with Minkowski coordinates as initial values for X^a, T, we observe that the part of the solution

before horizon formation is already the complete solution. The part behind the horizon is unphysical in ether theory. Similarly, solutions which do not allow a harmonic time-like coordinate are forbidden. Especially, there cannot be solutions with non-trivial topology or with closed causal loops.

4 Quantization

Quantization of a condensed matter theory in a classical Newtonian framework is unproblematic. The theory solves the problem of quantization of gravity in the trivial way, by an explicit, physical regularization. The preferred Newtonian framework avoids most conceptual problems of canonical quantization of general relativity (problem of time [7], topological foam, unitarity and causality problems [6] and so on), allows to define uniquely local energy and momentum density for the gravitational field as well as the Fock space and vacuum state in semi-classical theory. The introduction of a preferred frame hypothesis does not require any modification in special-relativistic QFT. Hawking radiation occurs similar to semi-classical GR. The collapsing star evaporates by Hawking radiation before forming a horizon – a scenario which has been discussed for GR too [5].

The existence of a preferred frame in our theory allows realistic causal hidden variable theories like Bohmian mechanics [3], despite the violation of Bell's inequality [1]. In this preferred frame, hidden information may be distributed FTL without causality violation. In the authors opinion, the EPR principle of reality [4] or causality are much more fundamental principles compared with observable physical symmetries like local Lorentz invariance. To reject realism following Bohr [2] or causality [10] is close to an immunization of relativity. The fact that both realism and causality may be saved with a preferred frame is a very strong argument in favour of a preferred frame [12].

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